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A REVIEW OF THE INVESTIGATIONS CONDUCTED IN WESTERN CANADA ON ROOT ROTS OF CEREALS[1]

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INTRODUCTION

The diseases of cereal crops commonly referred to as root rots, foot rots, or root diseases are world wide in distribution. In Western Canada the importance of these maladies soon became evident and research work was immediately started. During the past two decades these investigations have developed into studies of considerable magnitude. It will be necessary at first, for the sake of proper perspective, to mention some of the foreign contributions in this field. Before written records were available, however, we know that the growing of cereal crops was one of man's chief agricultural occupations. The pages of history contain frequent reference to crop losses attributed to insects and the more vague blights, mildews and rusts. It is very likely that the early husbandman was quite familiar with the cereal rusts and smuts because of the conspicuous field characteristics of these diseases. It is equally probable that the root rots were at that time, and as frequently happens now, included in the general category of "crop loss" or "crop failure". There is a possibility nevertheless that some of the early references to blights, should be interpreted as referring to root rots or certain manifestations of these maladies. As the study of agriculture and biology developed particularly through the 18th and 19th centuries, some investigators were able to define, and more or less investigate, cereal diseases which are now known as root rots.

CONTRIBUTIONS FROM FOREIGN COUNTRIES OTHER THAN THE UNITED STATES OF AMERICA

It appears that during the early years, most of the fungi which cause root rots had been studied by the mycologist before pathological investigations were undertaken. It is to be expected, therefore, that the first accounts of fungoid diseases would originate in countries where mycology had received considerable attention. A good list of early mycological and pathological literature pertaining to foot rots or root rots has been compiled by Stevens (123). A review of the literature on these diseases containing most of the earlier references will also be found in Sorauer's handbook (118).

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Ophiobolus graminis Sacc. was one of the first fungi studied in association with foot disease of wheat. Subsequent investigations have firmly established its parasitism and virulent nature. It has been less frequently reported as attacking other cereals. *Leptosphaeria herpotrichoides* de Not., on the other hand, was commonly found in cases of foot disease in all of the common cereals and often in association with *O. graminis* on wheat. Crop losses caused by a form of foot disease or foot rot in which these two fungi were involved brought forth many contributions from European investigators, especially towards the end of the 19th century. In 1890 there appeared a report by Prillieux and Delacroix (81) on foot rot of cereals in France; Hiltner (53) contributed a paper from Germany in 1894. Other early reports which may be noted are several papers by Frank (cited by Stevens) (123) discussing foot rots in Germany; contributions from France were published in 1898 by Mangin (64) while Peglion (80) the same year reported on his studies in Italy. It is of interest to note that as early as the middle of the 19th century a disease of the take-all type was receiving attention in Australia (1). Contributions by McAlpine (69) in 1902 and later by others, confirmed the earlier reports. It is quite likely that this form of root rot was also the one commonly known in England and reported by Smith (114) in 1884.

Another important type of cereal foot rot or root rot is that caused by various species of *Fusarium*. All cereals and most other grasses are attacked by these fungi. In the early European literature a disease of winter rye and winter wheat called snow-mould received considerable attention. The cause of the trouble was later determined as *Fusarium nivale* (Fr.) Ces. (*Calonectria graminicola* (Beck. and Brm.) Wr.). This disease was credited with causing extensive damage some seasons. It was recorded by Knutberg (57) as occurring in Sweden as early as 1768. What appears to have been a Fusarium type of root rot of cereals in England was referred to by Smith (114) in 1884. Sorauer (116, 115, 117) from 1901 to 1903 published several contributions on the problem of snow-mould disease in Germany. Additional reports on snow-mould and other Fusarium root rots may be cited as follows: From Denmark a report by Mortenson and others (68) in 1910; from Germany in 1912 by Schaffnit (101) and from France in 1914 by Mangin (65). A summary of the literature will be found in the recent book by Wollenweber and Reinking (134) which appeared in 1935.

The type of root rot caused by *Helminthosporium sativum* Pammel, King, and Bakke seems to have been of rare occurrence in Europe. It is primarily a disease of wheat and barley. This root rot was not mentioned in the reviews by Sorauer (118) or Stevens (123). According to McKinney (73) there is good evidence that Palm (79) in 1918 in a report from Java, and Hamblin (45) in an account of foot rot of wheat in Australia in 1922, were dealing with *H. sativum*. Recently the disease has been reported by Russell (85) as occurring in England and in Germany by Boning and Wallner (11). The infrequency of reports on this root rot from European sources is of particular interest since, as will be shown later, it is one of the major root disease problems on the North American continent.

The early foreign literature contains very few references to *Pythium* spp. as being associated with root rots of cereals. Eriksson (28) mentions

P. de Baryanum Hesse as attacking barley causing seedling blight. The significance of these fungi in cereal root rot studies appears to be a recent development.

CONTRIBUTIONS FROM THE UNITED STATES OF AMERICA

In the United States the study of root rots commenced early in the 20th Century, and progress was rapid. The knowledge which had been accumulated in Europe on these diseases was available to most of the American workers and was of great assistance to them.

The take-all type of root rot will be considered first. In 1902, Cordley (20) described a disease of wheat occurring in Oregon, which he considered to be a form of foot rot or root rot. McKinney (71) later considered it very likely that this was a case of take-all caused by *Ophiobolus graminis* or a disease of that type. He also cites references reporting what appears to have been take-all root rot attacking wheat in Maryland as early as 1802. According to McKinney (73) the first definite case of take-all was collected in Virginia in 1919 and reported by Schoene (102). It is very likely that this disease was involved in the trouble reported by Dana (22) in 1919. It was reported from New York State in 1920 by Kirby and Thomas (56) and a few years later, 1925, Kirby (55) published a full account of his investigations on this disease, bringing the information up to date. For recent contributions one is referred to papers by Fellows (29, 30), Fellows and Ficke (31), and Sprague (119).

Another type of root or foot disease of cereals, especially winter wheat, which should be considered at this point is that caused by *Cercosporella herpotrichoides* Fron, and recently described by Sprague and Fellows (121). The pathogen invades the basal parts of the plant but not the roots, producing incidentally a case of true foot rot. This fungus has been considered by many workers as the conidial stage of *Leptosphaeria herpotrichoides* but there has been no definite evidence on this point. It was concluded in the work just mentioned and in an earlier report by Sprague (120) that *C. herpotrichoides* was the primary cause of the Columbia Basin foot rot. The disease is quite similar in many respects to the "straw breaking" foot rot caused by *Leptosphaeria herpotrichoides* frequently reported from Europe. The relationship between the two fungi is consequently of considerable pathological interest.

The common types of root rot, however, were really the first to be given serious attention by American investigators. In 1909, Bolley (8) working in North Dakota was well aware of the importance of these diseases. Several early contributions to the study were made by Selby and Manns (103) in 1909, Bolley (9, 10) 1910 to 1913, Beckwith (7) in 1910, and others working in the Western States. These investigators isolated or collected various fungi such as species of *Fusarium*, *Helminthosporium*, *Alternaria*, *Macrosporium*, and *Colletotrichum* as well as *Gibberella saubinetti* (Mont) Sacc. all of which are recognized today as being associated with common root rot. In 1919 there was a severe outbreak of a disease in the wheat crop of Illinois which received much attention and which was thought to be a foot rot. Steven's (124) investigations of this disease indicated that a *Helminthosporium* was the cause. McKinney (71, 74) in later investiga-

tions came to the conclusion that the primary cause of the trouble was of virus origin. Outbreaks of this nature, however, undoubtedly stimulated investigations on root rots. There appeared during the following years several comprehensive accounts of root rots caused by *Gibberella saubinetii* and *Helminthosporium sativum* mainly, and other fungi to a lesser extent, Atanasoff (4) Dickson (24), L. Stakman (122), Christensen (18), McKinney (72) and Henry (47).

Pythium spp. which are associated with a major root rot in Western Canada have not been reported as a serious parasite of wheat or other small grain crops in the United States. There have been, however, several accounts of rather serious *Pythium* infections causing root rots of corn and sugar cane. For corn we may mention the papers by Valleau, Kerraker, and Johnson (126), Johann, Holbert, and Dickson (54) and Drechsler (26), and for sugar cane, Edgerton, Tims, and Mills (27) and Rands and Dopp (82).

The snow-mould disease so frequently referred to by European investigators as a major cereal disease, appears to have been of minor importance on this continent. The recent account by Dahl (21) however, indicates that this malady may cause serious damage to turf grasses.

INVESTIGATIONS ON CEREAL ROOT ROTS IN WESTERN CANADA

The Period from 1900 to 1920

As in other countries, notably the United States, this was a period of pioneering in plant pathology. The more conspicuous diseases of cereals such as rusts, smuts, ergot and mildews were well known. The reports of the Dominion Experimental Farms for this period, however, do not mention a definite case of root-rot disease in our grain crops. The first report of interest to workers on root diseases appeared in the 1911 annual report of the Dominion Botanist (41), Dr. H. T. Güssow. He described a discolouration of wheat kernels which is similar to, if not identical with, what is known to-day as fungous black point or smudge, frequently caused by *Helminthosporium sativum*. The samples containing such discoloured kernels had been received from Ontario and Saskatchewan. A year later, Güssow (42) reported *H. sativum* as occurring on barley at Ottawa. By 1914 the annual losses in the grain crops of Western Canada from rusts and smuts caused considerable concern. The Dominion Botanist (43) in his report for that year stressed the importance of specialization in plant pathological investigations. He also mentions receiving reports of obscure grain diseases from Southern Alberta. Wheat scab, a disease caused by *Fusarium* spp. was reported in 1916 by Güssow (44) as being prevalent in the Maritime Provinces. These fungi are frequently involved in common root rot of cereals. The same year, according to recent correspondence with Dr. Güssow, he collected a sample of diseased wheat plants at Scott, Sask. The unhealthy plants, which were pointed out to him by the superintendent of the Experimental Farm, were short, bleached and bore empty heads. On his return to Ottawa he examined the specimens and found one incomplete perithecium containing only one *Ophiobolus* ascus. At that time Dr. Reddick of Cornell University was visiting Ottawa and he con-

firmed the diagnosis. In 1919 a brief report drawing attention to the take-all disease was issued by the Dominion Botanist (2).

Towards the end of the period under review research work on cereal diseases was well established under the supervision of Prof. W. P. Fraser who at that time was in charge of the Dominion Laboratory of Plant Pathology at Saskatoon. Henry (46) working at Saskatoon isolated *Helminthosporium sativum* from wheat, rye and barley and successfully inoculated these grains with this fungus and observed the usual root rot symptoms.

The Period from 1921 to 1930

During this period we see a rapid development in plant pathological work in Western Canada. The investigations on root diseases expanded as an integral part of this development. Investigations were well established at the Dominion Laboratory of Plant Pathology, Saskatoon, in 1921. Laboratories for similar work were opened up in Manitoba in 1923 and in Alberta in 1927. A certain amount of pathological work was also carried on by the three universities of the Prairie Provinces. It was towards the end of the period, however, before distinct emphasis was placed on research in root diseases.

Workers in this field soon observed that the name root rot or foot rot was a general term referring to several distinct types of disease. The three types most frequently found were,—take-all, browning, and common root rot. There are some additional forms of uncertain status in the light of our present knowledge. In this review the literature will be considered according to the disease type where possible.

Take-all Root Rot

This disease is caused by *Ophiobolus graminis* Sacc. It attacks wheat primarily, barley to a slight extent, and oats very rarely.

The first published report of this disease in Canada was made by Fraser (32, 33) in 1923. At that time the disease appeared to be well established in northeastern Saskatchewan, and several fields showed severe injury. As take-all was known to be of major economic importance in Australia and other countries, this discovery caused considerable anxiety. A study of the disease was commenced by Russell (86) in 1924. It was reported from Manitoba by Bailey (5) in 1925 and was collected the same year in Alberta by Scott (92). Two years later Sanford (93) reported on several collections made in Alberta. These reports indicate the wide distribution of this potential menace to wheat farming. A brief progress report of the work conducted at Saskatoon was given in 1926 by Fraser, Simmonds, and Russell (34). In 1927 Russell (87) prepared a pamphlet giving the results of his laboratory and field investigations in respect to the control of this root rot. It was shown that the disease could be combatted by proper crop rotations, which consisted largely in not sowing wheat on infested fields for a year at least. A field showing take-all in severe form could be summer-fallowed the following year and then sown to oats or some other non-susceptible crop. It was pointed out, moreover, that grasses may harbour the pathogen and this must be kept in mind when applying control measures. An extensive survey in Alberta in 1927 by Sanford (94)

indicated that take-all was very prevalent and destructive in the semi-wooded zones of black soil, but comparatively rare in open grass plains of brown soil. The suppressing effect of crop rotation on the disease was observed. Another contribution from Russell (88) appeared in 1930. Field studies had shown that the disease was confined mainly to the semi-wooded areas of Saskatchewan. The trouble was most prevalent and destructive in wet seasons. Additional evidence was obtained to show that simple crop rotations would control this root rot satisfactorily.

Browning Root Rot

This is primarily a disease of wheat. The invasion of the roots by *Pythium* spp. especially when the plants are predisposed by unfavourable conditions, is generally considered to be the cause of this disease.

We have verbal accounts of the field characteristics of this root rot from Prof. W. P. Fraser and Dr. D. L. Bailey who had examined diseased fields in southern Saskatchewan in the early years of the period under review. The trouble, for many years, was particularly severe in the Indian Head district. Simmonds (105) in 1926 reported *Pythium*-like bodies in the roots of wheat plants suffering from a disease of this type. The chief characteristics of the malady and the etiological factors involved remained obscure until 1929 when Vanterpool and co-workers (131, 132) published the first of a series of papers. The disease was found to be widespread in Saskatchewan. The symptoms were most conspicuous in June on the summerfallow crop and the afflicted plants were noticeably retarded. This delay in growth exposed the crops to injury from rust and frost. Several isolates of *Pythium* were readily obtained from diseased roots and found, by inoculation tests, to be definitely parasitic. A new fungus, *Lagena radicicola*, Vanterpool and Ledingham, related to the *Pythiums*, was isolated in this work and reported for the first time. These contributions placed the browning root-rot investigations upon a firm foundation. Robertson (83) collected specimens in Alberta in 1930.

Common Root Rot

This term includes the types of disease resulting from *Helminthosporium sativum* and *Fusarium* infections of roots and basal parts of our cereal plants. It may be extended to include also infections and symptoms of a similar nature caused by other fungi.

In 1922, Simmonds (104) reported on preliminary studies of common root rot in oats. Various *Fusarium* isolates were obtained from diseased plants and pathogenicity tests conducted. Work on the general problem of common root rot was commenced at Winnipeg in 1923 by Bailey and Greaney (6). Similar studies were started by Sanford (94) in Edmonton in 1927. The same year Greaney and Bailey (36) published the results of their investigations conducted at Winnipeg. They obtained a large number of *Helminthosporium sativum* and *Fusarium* isolates from infected wheat roots. Pathogenicity tests showed that many of these were very virulent. Considerable attention was given to the matter of crop rotations and common root rot, but conclusive results were not obtained. This indicated that further studies were necessary to determine whether cultural methods, such as crop rotations, could be used as control measures. They did obtain some control, however, by the use of Semesan solution as a seed

treatment. A year later Simmonds and Scott (112) gave the results of their greenhouse tests on the use of seed treatments. It was found that many of the fungicides on the market at that time gave excellent results in controlling seedling blight of wheat, oats and barley. Formalin and sulphur treatments were unsatisfactory. In 1928 Simmonds (106) published the results of his investigations on common root rot of oats caused by *Fusarium culmorum* (W. G. Smith) Sacc. This disease appeared to be of rather common occurrence in Western Canada and probably is responsible for considerable injury in the oat crop some seasons. Under suitable conditions the pathogen readily invaded the root and crown tissues. With the exception of seed treatments, which protect the early seedling stage, no definite control measures were determined.

Contributions of General Interest

Some general aspects of the root rot problem were outlined by Sanford (95) in a paper which appeared in 1927. A circular describing the prevalent types of root rot was prepared at the Dominion Laboratory, Saskatoon, and issued in 1929 (3). The same year Henry and Foster (52) reported the collection of *Leptosphaeria* foot rot in Alberta. This was the first time this disease had been observed in Canada. In some respects it resembles the take-all root rot, and according to reports is a serious trouble in Europe. The first of a series of papers by Simmonds and co-workers (109) on the development of the wheat plant particularly in regard to root injuries appeared in 1929. In the first contributions it was shown that root amputations at different stages in the plant's development resulted in reactions somewhat similar to those caused by root parasites. It might be well to point out at this time that work on root rots was greatly stimulated by the formation of the Associate Committee on Field Crop Diseases of the National Research Council, which offered an opportunity for the workers to get together and discuss their problems. In 1930 one of the chief subjects of discussion at the meetings of this committee was the proposal for developing "plant disease" or "root-rot gardens" at various points in Western Canada (37). The problem of adding inocula, consisting of cultures of various pathogens to the soil to provide a suitably infected area for the testing of cereals, was found to be a difficult one. Consequently, most attempts to make such a garden were unsuccessful. Some of the reasons for these failures will be discussed later. Towards the end of this period we have a brief note by Vanterpool (127) on the occurrence of *Asterocystis radicis* de Wild in the roots of cereals and a short account by Simmonds (107) on a washing device for use in making isolations.

A survey for plant diseases in Canada was organized in 1920. Much useful information on the occurrence of root-rot diseases will be found in the survey reports (25, 70, 19).

The Period from 1931 to 1936

In the previous section most of the contributions dealt with the discovery and definition of the various root rots. The analysis of the root-rot complex and exploration work will need to continue for many years and especially will this be true if there are fundamental changes made in our western agricultural practices. During the particular period under

review, however, we see the appearance of many contributions dealing with special phases of the root-rot problem, such as soil microbiology, mycology, methods, the normal and pathological morphology of the host, as well as seed, fertilizers, and nutritional problems. Plant breeding aspects in regard to root rot have been under investigation but no comprehensive publications have appeared.

Take-all Root Rot

The pathogenicity of *Ophiobolus graminis* as influenced by other micro-organism was studied by Sanford and Broadfoot (99) and the results published in 1931. Most of the micro-organisms used in the investigation had been originally isolated from the soil and included fungi, actinomyces and bacteria. They observed that many of the cultures or culture filtrates suppressed the pathogenicity of *O. graminis* while some increased its virulence. The significance of such biotic relationships in a study of root diseases was immediately evident to workers in this field. This contribution and one the same year by Henry (48), which is reviewed below, went a long way towards explaining the many failures with root-rot gardens. These findings had a marked influence in determining subsequent trends in problems where the soil flora had to be considered. The following year Robertson (84) reported upon his histological studies on the infection of wheat caused by root-rot fungi, particularly *O. graminis*. It was shown that thickening of cell walls and lignification which occur with advancing age, will notably inhibit penetration and invasion of root and crown tissues. Henry (50) in continuing his studies of soil factors and root-rots, found that infections of wheat seedlings with *O. graminis* might vary greatly depending upon whether the soil was sterilized or not. In unsterilized soil the inoculum was quite ineffective at high temperatures (above 20° C.) in comparison with its virulence at lower temperatures. Such irregularities were not observed with sterilized soil and it was concluded that the natural soil flora was involved in these reactions. In 1933 we have the results of Broadfoot's (13) studies on the relationships between various soil micro-organisms and *O. graminis* when cultured together. He found many cases of compatability as well as antagonism in the 66 cultures tested. There was, however, no correlation between the reactions in culture and the infection of wheat seedlings by this fungus. Russell (89) in 1934 prepared a technical bulletin giving a complete account of his study of take-all root rot in Saskatchewan. In addition to his contributions (87, 88) previously mentioned, it should be noted that extensive host range studies failed to reveal any wheat variety or related species as being resistant to *O. graminis*. Most of the cultivated and native grasses tested, were also found to be more or less susceptible. On the other hand, oats, corn, and all non-grass species tested were very resistant. It was observed that different isolates of the pathogen varied a great deal in their virulence. Crop rotations were found to be the best method of control; it was strongly recommended that summer-fallow and crops resistant to *O. graminis* should be alternated with wheat. The following year Davies (23) contributed a brief paper showing the superiority of silver nitrate over mercuric chloride as a surface sterilization agent for isolating *O. graminis*. In 1936 Padwick (76) published an account of his studies on *O. graminis* showing that a certain growth

factor was necessary for the development of this fungus. It was suggested that growth factors may play an important part in the establishment of a balance between soil micro-organisms. Another paper by the same author (77) soon followed dealing with the possibility of biologic strains in *O. graminis*. The same year Russell (90) issued a circular bringing the information on take-all root rot up to date especially in regard to control measures.

Browning Root Rot

A paper published in 1932 by Vanterpool and Truscott (133) showed that progress was being made in the investigations on this root rot. Further evidence indicated that *Pythium* spp. were involved and very likely were of major importance in the onset and development of this disease. Two new species were isolated from diseased roots and described, *Pythium arrhenomanes* var. *canadensis*, Vanterpool and Truscott and *P. volutum*, Vanterpool and Truscott. Tests in the greenhouse showed that infection and injury increased with both an increase in soil temperature and soil moisture. In a later paper which appeared in 1935, Vanterpool (130) presented data from greenhouse and field experiments which should give considerable guidance in the development of reliable control methods. It was shown that soil samples from diseased patches were lower in available phosphorus and higher in nitrate nitrogen in comparison with similar samples from adjacent areas producing a normal crop. Furthermore, plant analysis revealed a low total phosphorus and high water soluble nitrogen content for diseased plants although protein nitrogen was low. It seems quite possible, therefore, that the disease is influenced by the phosphorus-nitrate ratio; when this is high, the disease is inhibited. The results of these tests give support to the general practice of applying phosphate fertilizer in the control of browning root rot.

Common Root Rot

Early in 1931, Henry (48) published the results of his studies on the natural soil micro-flora in relation to foot rots of wheat. This paper, as mentioned above under "take-all" (99) was one of the several valuable contributions on the interesting problem of the inhibitive or antagonistic action of certain micro-organisms. In this particular investigation it was shown that the natural microflora of the soil had a marked inhibitive action upon the pathogen *Helminthosporium sativum*. Under suitable conditions, this action was sufficient to reduce and largely prevent root injury resulting from infections by this fungus. Somewhat similar reactions were observed in tests with *Fusarium graminearum* Schwabe, another common root-rot fungus. This contribution and others along the same line have been of great value to workers in the field of root pathology. In a later paper the same year, Henry (49) presented data to show that sporulation in *H. sativum* was inhibited by soil micro-organisms. In 1933, we have contributions from Machacek and Greaney (60, 61) on the infection of cereal seedlings by *Fusarium culmorum* when injured seed was used. They proved by inoculation tests that plants from injured seed suffered more severely than those from sound seeds under similar conditions. About the same time Mead (66) published the results of his investigations on a similar problem. He found that wheat seed injured by frost, rust, sprout-

ing, drought or formalin was more susceptible to infection and injury by *Helminthosporium sativum* than was sound seed. In 1935, Gordon (35) published his first contribution on the taxonomy of *Fusarium* spp. These fungi are invariably isolated from diseased plants and not infrequently from apparently healthy plants. The taxonomy of the *Fusaria* has always been a source of confusion to the pathologist. Consequently the work which Dr. Gordon is doing will assure a sound foundation for this phase of root disease studies. The same year we have a report from Sallans (91) on methods of inoculating wheat with *Helminthosporium sativum*. He found mash culture inoculum rather unsatisfactory and devised a modified spore suspension method. The seed was dipped in the suspension, incubated for a short period and then dried. The fungus was well established on the seed in this way and good infections resulted. Seed so treated was easy to handle and could be sown with a seeder. The following year Broadfoot (16) published a paper showing that common root-rot fungi such as *Helminthosporium sativum*, *Fusarium culmorum* and *Fusarium* spp. were readily isolated from wheat plants. He made isolations from plants collected from some of the various rotations being tested on the Dominion Experimental Farms located in the Prairie Provinces. He concluded that environmental factors associated with climatic changes and location have a greater influence on the number of fungi than rotations or other cultural practices. A short time later we have the results of extensive pathogenicity tests conducted by Sanford and Broadfoot (100). They tried a large number of *H. sativum* and *F. culmorum* isolates against wheat in greenhouse tests and found that virulent strains of either fungus were rare. It was pointed out, however, that a great improvement in technique is needed before reliable experiments of this kind can be conducted under greenhouse conditions. It was suggested that possibly more attention should be given to the reaction of plants beyond the seedling stage. We may conclude by reviewing four papers from Manitoba. In 1934, Greaney and Machacek (39) gave a report on their results in devising field methods for the study of common root rots. They emphasized the planning of plots, disease rates, inoculation technique and the statistical analysis of results. The following year Greaney and Machacek (40) published the results of some greenhouse tests which showed that the saprophytic fungus *Cephalothecium roseum* Corda suppressed the parasitic activity of *Helminthosporium sativum*, when both were used in inoculation tests with wheat. It was believed from the evidence obtained that toxic substances produced by the saprophyte were responsible for the reaction observed. A later paper by the same authors (62) presented results showing that some of the new dust fungicides used as seed treatments for wheat, definitely reduced root-rot injury. *Helminthosporium sativum*, *Fusarium culmorum* and *Fusarium* spp. were the fungi studied in their experiments. In 1936, these investigators (63) contributed additional data to show that plants from injured seed are more subject to infection and injury by root-rot fungi, than plants from sound seed. They worked with *Fusarium culmorum* in greenhouse and field inoculation tests of wheat. The use of clean sound seed was strongly recommended to prevent injuries of this nature.

Contributions of General Interest

In continuing their studies on the development of the wheat plant especially in reference to root growth, Simmonds and Sallans (110) pub-

lished an account in 1933 of some tests on amputating roots. It was shown that the seminal roots, often referred to as temporary roots, are in reality quite permanent. Moreover, injury to these organs will be reflected in a reduced yield and retarded growth, causing delayed ripening; this is particularly true if the injury occurs during the seedling stage. On the other hand, crown root amputations appeared to hasten ripening while also reducing the yield. There were indications of a similarity in reactions between injuries of this kind and those resulting from certain fungous infections. The same year Padwick and Henry (78) contributed a paper which revealed the important relationship between many of the cultivated and natural grasses and the root-rot diseases. The evidence indicated that most of the grasses may be infected by and harbour fungi which cause root diseases, particularly *Ophiobolus graminis*. Furthermore, they pointed out the significance of such hosts in encouraging the survival of pathogens during the summer-fallow year as well as the tendency for a disease like take-all root rot to be more severe following grass crops. Results from a later paper by Henry (51) indicated that generally there was less damage from root rots following summer-fallow. In certain cases, however, it was apparent that the take-all fungus had survived in sufficient amount to cause considerable injury in the following wheat crop. In a paper appearing also in 1933 Broadfoot (12) submitted evidence to show that wheat seedlings were more susceptible to infections by root-rot fungi than were older plants. He states, however, that although age was probably a factor, yet there were many other factors influencing infectivity and definite conclusions were not possible. Simmonds and Sallans (111) gave a further report on their studies of the wheat plants especially in regard to root development. It was shown that the mode of growth for the season had rather definite characteristics and could be divided into three periods: *(a)* from seeding to crown root development, (b) elongation of the culms, and (c) ripening. In dry seasons crown roots were poorly developed and the plant was dependent upon the seminal roots almost entirely. A new angle on the problem of disease resistance, in so far as Canadian workers were concerned, was opened up by the chemical and micro-chemical studies conducted by Tyner (125). He investigated the changes which took place in the wheat plants, particularly the roots, when grown under different environmental conditions. The preliminary nature of the study forbade definite conclusions but it is hoped that further investigations along this line will be undertaken. Early in 1934 we have a paper by Broadfoot (15) dealing with rotations in regard to root rots. He was concerned primarily with the common root rot type. The results indicated an increase in disease where wheat followed wheat, barley, or western rye grass, and very little disease in wheat after summer-fallow, oats, or sweet clover. Padwick (75) a year later published further evidence to show that many grasses were definitely instrumental in the survival and spread of root-rot fungi. The same year Simmonds, Russell, and Sallans (113) published the results of their study on diseased and normal root systems of wheat. In common root rot the infections of the roots and base of the plant were usually slight and the progress of invasion, through the season, was slow. This resulted, however, in a retarded growth and a reduction in yield. In the take-all type, the infections were more severe and conspicuous resulting in pre-maturity, destruction of tillers, and marked reduction

in yield. In plants affected by browning root rot, the infection involved primarily the lateral rootlets, causing a distinct retardation of growth with a decrease in yield approximately the same as that noted for take-all.

There also appeared during this period several articles which need not be reviewed but should be recorded for those who wish further information on the respective topics: a general review of some soil microbiological problems in Western Canada, by Sanford (96); a study of methods for the isolation of fungi, Mead (67); a new root-rot disease of oats described by Sanford (97, 98); a new fungous parasite found in the roots of wheat and described by Ledingham (58) and a paper by Broadfoot (17) on the chemical control of snow-mould of turf in Alberta. The following references should also be added to complete the contributions of this period: Vanterpool (128, 129), Greaney and Machacek (38), Broadfoot (14), Machacek (59), and Simmonds and Mead (108).

SUMMARY AND CONCLUSIONS

Generally speaking the study of root rots was undertaken somewhat later than the study of the more conspicuous diseases such as rusts and smuts. In European countries root rots or foot diseases of cereals were being investigated towards the end of the 19th century. About twenty years later we have reports of investigations in the United States. In Canada there were few observations bearing directly upon the root-rot problem, previous to 1920. Work upon common root-rot was started soon after this time. Then with the discovery of take-all in 1923, investigations on the entire subject of root pathology were greatly stimulated. The early studies on take-all root rot soon led to sound recommendations for its control. Later work has supported the early recommendations with only slight modifications. The studies leading to the control of this root rot are contributions of real value to Western Canadian agriculture. It is certainly advisable, however, for the investigations to continue, for a period of wet years might once more bring this parasite into prominence. Furthermore, the take-all fungus is harboured by and develops readily on the roots of most grasses; consequently the recent tendency to increase the grass acreage, which undoubtedly is good agricultural practice, must be considered as of pathological interest if such land is again to be broken and sown to wheat.

Contributions of equal, if not greater, value have been made in the study of browning root rot. Only a few years ago when epidemics of this disease occurred in Saskatchewan, the pathologists had little information to offer the perplexed wheat grower. This root rot was invariably most severe on the summer-fallow crop which incidentally constitutes the main wheat crop over a large area of Saskatchewan. Moreover, the crops on the well prepared fallow often suffered the greatest damage. Diseased fields were also delayed in ripening. These characteristics indicated, therefore, a problem of unusual interest and importance. The investigations of recent years have thrown a great deal of light on the etiological factors involved. The use of phosphate fertilizers, certain cultural practices, and seed treatments can now be recommended as having definite preventive value. There is a great need, however, for additional work upon this root rot. The elusive nature of the trouble suggests further investigations

upon the ecological factors concerned. If, for instance, one could predict the probable appearance of the disease, then control measures could be applied most effectively.

A great deal of information has been accumulated on the common root-rot group, but no specific control recommendations can be offered as yet. Generally speaking certain seed treatments will reduce infection and injury during the early seedling stage, and proper crop rotations will also reduce injury. Most of the recent work has had to do with methods and technique in an endeavour to devise reliable experimental procedure. In this respect there have been many contributions of stepping-stone importance, leading towards the proper evaluation of the problem and suggestive of future investigational trends.

In developing control measures, plant breeding and selection have been of little direct help. Extensive tests with the take-all fungus failed to reveal any wheat variety showing clear-cut resistance. Preliminary tests with the browning root-rot fungi have not been encouraging. It is only recently that reliable testing methods have been worked out for experiments with the common root-rot fungi, and these trials have shown indications of resistance in some varieties.

In conclusion we wish to point out that although root-rot investigations in Canada commenced about 1921, comprehensive and co-operative investigations have been under way for only about 10 years. During these years, three major types of root rot have been defined and investigated. Good control methods are available for one type and fairly satisfactory measures for a second type. The researches on the third or common root-rot group, are well advanced. Consequently, if one reviews the results dispassionately, it must be apparent that considerable knowledge has been accumulated which should go a long way to assure sound cereal cropping practices for the future.

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A BIENNIAL BEARING RECORD OF AN UNPRODUCTIVE BALDWIN BLOCK

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Horticultural literature abounds in references to biennial bearing in apple trees, and is equally well supplied with suggestions on cause and cure. A record of an instance where biennial bearing is occurring even in the absence of full crops may be of interest.

In a cultural experiment being conducted at the Horticultural Experiment Station at Vineland, a preliminary report of which appeared in Scientific Agriculture 17 : 11, 1937, there were 54 Baldwin trees planted in 1921 (9 trees removed in 1938 for a highway) which now have a branch spread of about 27 feet. These trees have never borne a heavy crop but from the first there has been an established biennial habit. This may be seen from Table 1 showing the total yield per row per year, three trees per row, since they began fruiting.

It will be observed from Table 1 that biennial bearing occurs regardless of treatment. Rows 1 to 19 inclusive have received a minimum of cultivation since 1928. This consists of spring plowing and working until about May 15, when a green manure crop is sown. Rows 21 to 35 are spring plowed, kept cultivated until July 15 and then seeded to the crop used in the minimum cultivation plots.

To obtain some information on the reaction of manure under such conditions, barnyard manure was applied at the rate of 20 tons per acre to Rows 17 and 19 which received minimum cultivation, and to Rows 21 and 23 which received regular cultivation, in the autumns of 1935, '36, and '37. No response from the use of this manure was observed in 1936. In 1937 the autumn foliage of the trees on the manured plot was of a richer green and there was an appreciable difference in the growth of the green manure crop. During 1938 this latter effect was very marked. It is perhaps too soon to expect any influence from the manure on annual bearing, and although Rows 17 and 19 bore in 1938 much better than average, their 1937 crop was lighter. Certainly no improvement was registered in Rows 21 and 23. Until further crops are produced the high yields of Rows 17 and 19 in 1938 must be considered as simply coincidences, especially when the earlier yields, particularly of Row 17, are noted. The 1934 yields of Row 29 indicate how, in a given year, the yield may be out of line without altering the biennial trend.

In Table 1 the low yields of these Baldwin trees may be noted. Table 2 shows the total accumulated yield per tree for the varieties in this experiment.

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TABLE 1.—TOTAL YIELDS IN POUNDS FOR BALDWIN PER ROW PER YEAR (3 trees per row)

Row	Treatment	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	Total yields		Average yield per tree for each plot
												Row	Plot	
												lbs.	lbs.	lbs.
1		2	0	102	15	41	59	195	10	875	—			
3		38	0	67	5	26	0	24	3	680	—			
5		21	0	81	17	38	10	87	3	490	—			
7	Minimum cultivation,	18	0	5	16	31	3	9	7	430	16	535		
9	seeded about May 15	33	0	7	8	22	5	9	0	285	0	369		
11		28	0	109	70	142	35	217	7	562	5	1175		
13		1	0	46	27	114	23	120	3	487	26	847		
15		0	0	122	36	163	22	133	8	448	26	958	3884	259
17	Minimum cultivation plus manure,	0	0	78	21	42	94	41	7	380	207	870		
19	20 tons per acre, autumn 1935, '36, '37	9	0	59	1	32	7	57	0	435	180	780	1650	275
21	Regular cultivation plus manure, 20	23	0	48	0	14	15	83	4	605	18	810		
23	tons per acre, autumn 1935, '36, '37	0	0	10	7	83	5	146	3	588	10	852	1662	277
25		5	0	42	1	164	11	147	0	565	0	935		
27		15	0	36	1	81	19	107	7	701	0	967		
29	Regular cultivation to July 15; seeded	3	0	34	0	137	126	94	4	675	10	1083		
31	to same green manure crop as above	23	0	24	9	157	23	101	7	620	5	969		
33		12	0	8	8	185	66	182	18	445	5	929		
35		2	0	31	6	210	6	71	8	280	19	633	5516	306
Average (54 trees)		4.3	0	16.8	4.6	31.1	9.6	33.7	1.8	177	11.7*	282		

* Average of 45 trees.

At the end of 1935 the Baldwin trees had a total accumulated yield per tree of 100 lbs. as against 7 lbs. for the Spy trees. This illustrates further the unsatisfactory returns from Baldwin in this particular orchard. Spy is naturally late in coming into bearing but is rapidly overtaking Baldwin.

TABLE 2.

Variety	Number of trees in 1938	Total accumulated yield per tree (lbs.)
McIntosh	43	784
Duchess	74	603
Wealthy	73	502
Baldwin	45	282
Spy	41	238

SUMMARY

In this block of Baldwin trees a decided biennial bearing habit of fruiting has been established. Cultural treatments to date have not materially influenced this biennial bearing habit. Although a few trees have deviated somewhat from the average the general tendency of biennial bearing is well established even though at no time has an exhaustive crop been produced.

HONEY AS A STIMULANT TO THE ROOTING OF CUTTINGS[1]

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During the past few years, a great deal of work has been carried on to show the effect of various synthetic substances on the rooting of cuttings. In the late fall of 1938, several of the commercial preparations of these "Phyto-hormones" were being tested at the Central Experimental Farm for their comparative effectiveness in the rooting of coniferous cuttings. In conjunction with this test, cuttings of *Thuja occidentalis pyramidalis* were subjected to a series of treatments with ordinary honey. At the end of two months, these were removed from the bed, and looked so promising that a properly planned test was started with chrysanthemums to determine the value of honey as a stimulant to rooting.

MATERIALS AND METHODS

I. Units of 25 cuttings of *Thuja occidentalis pyramidalis* were treated as follows:

(a) Control.
(b) Dipped in pure honey and planted immediately.
(c) Stood in 50% solution of honey for 24 hours.
(d) Stood in 25% solution of honey for 24 hours.
(e) Stood in 5% solution of honey for 24 hours.

Cuttings were then planted in a closed propagating frame with bottom heat between 65° and 70° F.

II. Cuttings were taken of 5 varieties of chrysanthemums and were treated as follows, in units of 10 cuttings:

(a) Control.
(b) Auxan powder.
(c) Rootone powder.
(d) Fontastex.
(e) 20 ppm. naphthylene acetic acid for 6 hours.
(f) 25% solution of honey in water for 6 hours.

These cuttings were planted in an open propagating frame with bottom heat between 65° and 70° F.

RESULTS

I. Pyramid cedar cuttings were removed at end of twelve weeks. The results were as follows:

Treatment	*Rooted, %*	*Callused, %*
(a) Control		80
(b) Dipped in pure honey	25	60
(c) Stood in 50% solution honey 24 hrs.	44	44
(d) Stood in 25% solution honey 24 hrs.	64	29
(e) Stood in 5% solution honey 24 hrs.	32	60

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The results of treatment (d) compared favourably with chemically treated cuttings.

II. The following table shows the comparative results of control, Rootone and 25% honey on the 5 varieties of chrysanthemum cuttings. The other 3 treatments are omitted because space does not permit their inclusion in one table.

Variety	Control			Rootone			25% honey solution		
	Rooted, %	Av. no. of Roots	Av. length*	Rooted, %	Av. no. of Roots	Av. length*	Rooted, %	Av. no. of Roots	Av. length*
No. 97 (Korean)	90	12.5	1.0"	100	24.0	1.5"	100	22.0	1.5"
M. B. Davis	10	4.0	0.5"	75	7.1	1.25"	80	5.3	1.0"
Ella Sutherland	50	4.6	1.0"	100	7.4	1.0"	100	12.7	1.0"
Constance McKee	80	4.8	0.5"	100	9.6	1.25"	100	6.6	0.75"
Patricia Macoun	80	3.7	0.5"	100	10.2	1.5"	100	7.0	1.25"

* Average length of 6 longest roots on each cutting.

DISCUSSION

Rootone was chosen for the above table because in the test it proved to be the best of the chemical treatments. While 20 p.p.m. naphthylene acetic acid produced the greatest number of roots, it was obviously too strong, causing damage to the base of the cutting and production of very numerous short, stocky roots.

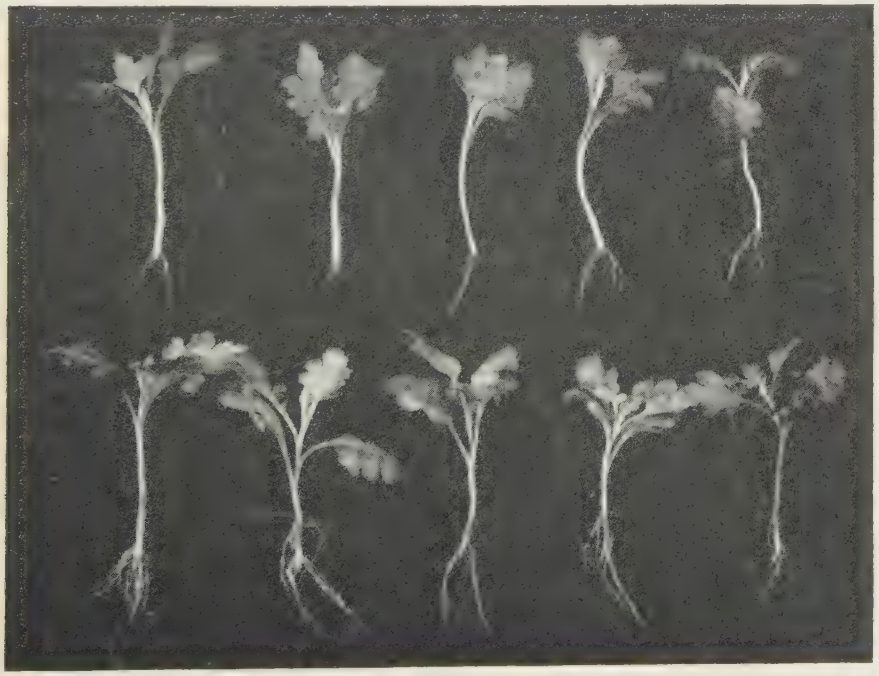

FIGURE 1. *Variety No. 97 (Korean):* Top control, bottom 25% honey for 6 hrs.

From the table, it can be seen that in each case honey caused a higher percentage of cuttings to root. There were also a greater number of roots per cutting and the average length of these roots was greater than in the case of the control cuttings. Rootone was superior in number of roots and lengths of roots per cutting, although the margin was not large.

SUMMARY

Honey has a definitely stimulating effect on the rooting of cuttings of Thuja and Chrysanthemum. This may be due to any one of many substances in the honey, or to a combination of two or more of these substances.

ACKNOWLEDGMENT

The writer wishes to express his gratitude to C. B. Gooderham, Dominion Apiarist, at whose suggestion this work was started.

THE RELATION OF BODY MEASUREMENTS TO THE FATTENING GAINS AND THE PERCENTAGE OF EDIBLE FLESH IN THE FOWL[1]

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The problem of the improvement of market poultry consists of a number of phases. Fundamentally, there is the question of determining the type or conformation best suited to the needs of the consumer. Secondly, from the producer's standpoint, the problem involves the difficulties of breeding such a type, and the economics of its growth and fattening qualities.

Consumer preference is based largely on the degree of fleshing, or plumpness, and the final dressed appearance. The standard grades for market poultry which have been set up recognize this fact. It is important, however, that the ideal market chicken should carry the maximum percentage of edible flesh.

The relation of the body type of a bird to its market classification or its percentage of edible meat has been the subject of several investigations. Maw (5) found differences between breeds in the percentage of edible meat. Harshaw (2) reported the differences in total edible meat between roasters grown on range and those confined, and between fattened and unfattened stock. The relation of the size of the bird to the edible meat and its value was reported by Halnan and Fermor (1) and Maw (6). Jaap (3) and Jaap and Penquite (4) have related the body measurements of turkeys and chickens to visual conformation groups, and conclude that differences in conformation of live birds may be expressed by comparing body weight, shank length, keel length, and minimum anterior depth.

There is, at present, a large variability in our common breeds with regard to type. The variability in type found in birds brought to fattening stations may be due largely to breed differences, but in addition to this there are differences in the body shape and in the percentage of edible meat of birds within the same breed. It is not known whether or not birds of different body conformation vary in their ability to fatten. The reaction of birds to the fattening process is another factor which may greatly influence the final dressed appearance. From the economic standpoint, the causes of individual variability should be determined, and as far as possible efforts should be made to control these. The data herein reported are concerned with the possible relation of certain body measurements, with the ability to make large gains when fattened, and with the percentage of edible meat on the carcass.

MATERIAL AND METHODS

As shown in Table 1, the data have been obtained from 243 birds of three pure breeds and the progeny of several crosses between these breeds.

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TABLE 1. MEAN WEIGHTS AND MEASUREMENTS ACCORDING TO BREED

Breed	B.P. Rock	White Rock	R.I. Red	B.P. Rock × R.I. Red	R.I. Red × B.P. Rock	White Rock × B.P. Rock	B.P. Rock × Buff Orpington	White Wyandotte × R.I. Red
Number	101	22	50	41	8	7	9	5
Initial weight (grams)	2815.69	2560.68	2375.70	2547.68	2507.50	2832.86	2783.88	3100.00
Gain—7 days (grams)	109.26	−13.18	−14.00	29.51	17.50	9.28	48.33	59.00
Gain—14 days (grams)	236.34	60.91	80.00	159.02	181.25	227.86	162.78	188.00
Feed consumed—14 days (grams)	2040.30	1816.86	1712.40	1883.65	1919.00	2373.14	2101.00	2211.40
Length of leg (cms.)	36.58	36.21	35.96	36.58	36.56	36.21	35.33	37.90
Length of body (cms.)	24.32	23.40	22.71	23.69	23.75	23.86	23.05	24.90
Depth of body (cms.)	12.92	12.82	12.38	12.48	12.70	12.68	12.58	12.28
Length of keel (cms.)	13.89	13.23	12.59	13.32	13.54	13.36	13.17	13.60
Circumference of tibial muscle (cms.)	15.08	14.16	14.19	14.48	14.05	14.57	15.00	15.80
Edible flesh (per cent)	56.40 (16)		55.18 (9)	53.23 (17)				

The different groups were mostly hatched and reared together, the feeding and management being as near alike as possible for all. The birds were placed in batteries for a 14-day fattening period when approximately mature in body development. The basal fattening ration used consisted of yellow cornmeal, 30 lbs.; ground oats, 30 lbs.; white middlings, 26.5 lbs.; and salt, 1 lb. To this ration were added varying percentages of animal protein supplement made up of beef meal, 7.5 lbs., and powdered buttermilk, 5 lbs. The varying percentages of animal protein used were found to have had no influence on the gains made (Maw *et al.*, (7)). The initial weight and gain attained by each bird on the seventh and fourteenth days were recorded. The following measurements were obtained from the dressed carcasses: A—length of leg, the fully extended length from the sole of the foot to the tip of the femur; B—length of body, from the anterior point of the shoulder to the tip of the upper posterior projection of the ischium; C—body depth, from the back vertebrae to the anterior point of the keel; D—length of keel: E—circumference of the tibial muscles at the point of greatest diameter.

Forty-two of these birds were then drawn and the flesh carefully separated from the bones and weighed. The percentage of edible flesh includes all meat, fat and skin removed from the skeleton, minus heart, liver, gizzard, and neck. The data from these birds have been used in the analysis of the percentage of edible flesh.

All measurements were taken to the nearest millimeter and weights to the nearest gram.

The methods used in the analysis are largely those outlined by Wallace and Snedecor (9) and Snedecor (8).

BREED DIFFERENCES

The means for all the observations made, according to the different breed groups, are presented in Table 1. The mean initial weights of the breed groups show considerable variation. This is to be expected, since no selection was exercised other than to pick birds sufficiently mature to be classed as large roasters. Table 2 gives the analysis of variance, and

TABLE 2.—ANALYSIS OF VARIANCE DUE TO BREED FOR INITIAL WEIGHT, FEED, GAIN, AND BODY MEASUREMENTS

Character	Source of variation					F	Necessary F	
	Total	Between breeds		Within breeds			5%	1%
	D/F	D/F	Mean Square	D/F	Mean Square			
Initial weight	242	7	1,244,159.93	235	93,211.29	13.35	2.04	2.72
Gain—7 days	242	7	105,860.99	235	26,298.79	4.02		
Gain—14 days	242	7	574,673.88	235	30,543.46	18.81		
Feed consumed—14 days	242	7	855,278.20	235	166,631.22	5.13		
Length of leg	242	7	5.29	235	2.88	1.83		
Length of body	242	7	14.47	235	1.49	9.72		
Depth of body	242	7	1.94	235	.532	3.65		
Length of keel	242	7	8.45	235	.591	14.29		
Circumference of tibial muscle	242	7	6.56	235	1.01	6.47		
Edible flesh (per cent)	41	2	41.81	39	33.44	1.25	3.24	5.20

the data for initial weight show that there are highly significant differences between some breeds.

The gains attained at the end of the 7-day period were quite variable. The final gains at 14 days were more uniform and showed a more definite difference between breeds. It has been found that the conditions necessarily imposed by individual feeding usually result in a temporary check to the bird's feed consumption. Consequently, little information can be obtained from the shorter feeding period data.

An inspection of the means for the various body measurements, given in Table 1, shows that the differences between the breeds are, in most cases, small. However, when subjected to variance analysis, it can be seen that, in the case of four of the measurements, the "between breeds" variance is significantly greater than that found for "within breeds", an exception being in the case of the length of the leg, where the F value is smaller than that necessary for significance. The differences between the means of the breed groups, with the small number of individuals, are, in most cases, not significant. Although these linear measurements in themselves give no clue as to the differences in body shape or conformation, the data suggest the desirability of correlating these differences with the value of the birds from the standpoint of their meat production.

The analysis of the variance of the percentage of edible flesh for three breed groups showed no significant difference "between breeds".

CORRELATION STUDIES

(a) Relation of Initial Weight, Feed Consumed, and Body Measurements to Gain

The correlation coefficients of initial weight, feed consumed, and the various body measurements with each other and with fattening gain at 14 days are shown in Table 3. These correlations have been calculated

TABLE 3.—CORRELATION COEFFICIENTS FOR GAIN

Variable	B	C	D	E	E	G	X
Length of leg (A)	.7028	.5478	.4641	.2937	.4232	.3338	.2579
Length of body (B)		.6124	.5613	.5578	.7205	.3315	.4442
Depth of body (C)			.5242	.4159	.4927	.3644	.4634
Length of keel (D)				.3332	.5442	.2683	.2611
Circumference of tibial muscle (E)					.6923	.4238	.5088
Initial weight (F)						.3273	.4167
Feed consumed (G)							.8059
						R^2	.7448
Multiple correlation coefficient						R	.8630
Necessary value for 5%—r =						R	=.243
Significance 1%							.277

from the variance remaining after removing the "between breed" variance. It can be seen that the correlations between one measurement and another range roughly between 0.29 and 0.72. The circumference of tibial muscle has lower-than-average correlations with length of leg and length of keel, while the correlation between the length of body and length of leg is higher than average.

With respect to gain, the correlations of body measurements and initial weight are more uniform, except those for length of leg and length of keel, which are lower than average.

These ratios suggest that the differences between the birds are not wholly general size differences, and that it is not general body size which is correlated with gain.

The multiple correlation coefficient of 0.8630 is highly significant. The square of this coefficient indicates that approximately 74% of the variance of the gain is due to the 7 variables which were measured. Table 4

Table 4.—Relative effect of independent variables on gain

Variable	Symbol	Standard Regression Coefficient	Percentage or weight	Partial Regression Coefficient (b)
Length of leg	A	−.2745	17.32	−28.26
Length of body	B	.3055	19.28	43.75
Depth of body	C	.1879	11.86	45.01
Length of keel	D	−.0898	5.66	−20.41
Circumference of tibial muscle	E	.0801	5.05	13.90
Initial weight	F	.0216	1.36	.012
Feed consumed	G	.7253	45.77	.310

shows the regression coefficients of gain on each separate variable. The coefficients for length of leg and length of keel are negative, and those for circumference of tibial muscle and initial weight are not significant. The percentage or weight which each variable bears to the total variance of gain is also shown in Table 4. It can be seen that feed consumed accounts for nearly as much of the variability as all the other variables combined. Initial weight has practically no effect on gain. Of the other variables, length of body has the greatest influence on gain. It should be pointed out that the seven variables together account for only 74% of the total variance. After removing the influence of the feed consumed, the remaining body measurements and initial weight influence the gains to the extent of approximately 40%.

The partial regression coefficients indicate the change in gain which might be expected per unit change in a body measurement independent of the changes in the other variables. The coefficients indicate that the gain decreased an average of 28.26 grams and 20.41 grams for each centimeter increase in the length of the leg and length of the keel respectively. Increases in gain occurred with unit increases in length of body, depth of body, and circumference of tibial muscle. There was an increase in gain of 0.3 grams for each gram of feed consumed.

These data suggest that, from a practical standpoint, the type of bird which will make the best gain is one with a relatively long and deep body, without too great length in the leg and the keel. However, these relationships apply to only approximately 40% of the total variability in gain, and, consequently, control of gain by means of the body measurements here considered would be relatively limited.

(b) Relation of Initial Weight and Body Measurements to Percentage of Edible Flesh

As shown in Table 1, the birds on which the percentage of edible flesh was determined were divided among three breed groups. The analysis of variance indicated that, in this sample, the differences in edible flesh between the breed groups were not significant. The results obtained in correlating the initial weight and body measurements with the percentage of edible flesh for this group of 42 birds are given in Table 5. The correlation ratios for the independent variables are small and in some cases not significant.

TABLE 5.—CORRELATION COEFFICIENTS FOR PERCENTAGE OF EDIBLE FLESH

Variable	B	C	D	E	F	X_1
Length of leg (A)	.5697	.3429	.3312	−.0169	.0799	−.3325
Length of body (B)		.3762	.5403	.1816	.4928	−.2527
Depth of body (C)			.3079	.1080	.3441	−.1787
Length of keel (D)				.2804	.4774	.1175
Circumference of tibial muscle (E)					.4440	.3276
Initial weight (F)						.1926
					R^2	.3331
	Multiple correlation coefficient				R	.5772
	Necessary value for 5% r = .304				R =	.538
	Significance 1% .393					.605

When considering the correlation of the initial weight and body measurements with the percentage of edible flesh, only two variables have a significant relationship. The length of leg has a negative correlation and the circumference of tibial muscle a positive correlation with edible meat. These values are not large, and, even though significant, further samples might give different results. The multiple correlation coefficient is barely significant. These data indicate that of the total variability in the percentage of edible flesh only 33% can be traced to the measurements taken.

Table 6 shows the regression coefficients and the percentage or weight which each variable bears to the edible meat. None of the standard regres-

TABLE 6.—RELATIVE EFFECT OF INDEPENDENT VARIABLES ON THE PERCENTAGE OF EDIBLE FLESH

Variable	Symbol	Standard Regression Coefficient	Percentage or Weight	Partial Regression Coefficient (b)
Length of leg	A	−.1463	10.17	− .2040
Length of body	B	−.4045	28.12	−1.2240
Depth of body	C	−.1603	11.14	− .5827
Length of keel	D	.2568	17.84	.8075
Circumference of tibial muscle	E	.2424	16.84	.8015
Initial weight	F	.2287	15.89	.0032

sion coefficients is significant. Length of body shows a slightly larger influence than the other factors. The regression in this case is negative, the *(b)* value indicating that an increase in body length of one centimeter led to a 1% decrease in edible flesh. Although not statistically significant, these data support the practical belief that the long-legged bird, with a large frame, generally carries a smaller amount of edible meat.

DISCUSSION

The results of this analysis with respect to gain indicate that, aside from the fact that fattening gain is, in a large measure, a function of the feed consumed, certain body measurements have a relationship to gain. It is possible that other measurements than those studied might have given higher correlations. The measurements taken are representative of those usually considered in judging the body type of a bird. Of the measurements taken, length of body was found to have the greatest weight in influencing the fattening gain.

Of particular interest are the partial regression coefficients which show that, in this group of birds, an increase in the length of leg and the length of keel led to a decrease in the gain. On the other hand, an increase in the length and the depth of body led to an increase in the gain. While all the correlations are positive, two of the regression coefficients, those for length of leg and length of keel, are negative. Snedecor (8) points out that this case may arise when length of leg and length of keel are slightly correlated with gain in the whole sample, but in groups alike, with respect to the other variables, gains are smaller among the birds with longer legs and longer keels.

The study of the relation between the body measurements and the percentage of edible flesh on a smaller group of birds indicates that length of leg and circumference of tibial muscle show significant correlations with percentage of edible flesh. However, when the other measurements are considered, these two are of less importance. Considering the regression coefficients, only one, that for length of body, is near the level of significance. An increase in this measurement led to a decrease in the percentage of edible flesh.

It would appear that certain of the body measurements under consideration are related to fattening gains and, to a smaller degree, to the percentage of edible flesh. However, since these relationships account for only about one-third of the variability in these two qualities, the extent to which changes in body type would lead to improvement in the dressed fowl is limited. This does not imply that body conformation should be neglected for obviously, even though its influence be limited, it is necessary to utilize fully every means possible in controlling the qualities desired.

SUMMARY

The correlations between certain body measurements and fattening gains are significant. Regression studies indicate that increased length and depth of body were associated with increased gains, while birds with longer legs and keels had smaller gains.

The relationships between the body measurements and the percentage of edible flesh were low. An increase in length of body was associated with a decrease in the edible flesh. The other regressions were not significant.

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THE CEREALS IN THE FATTENING RATION

I. THE COMPARATIVE EFFECT UPON GAINS AND COMPOSITION OF THE CARCASSES WITH MATURE ROASTERS[1]

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The extent to which the four common cereals, yellow corn, wheat, oats and barley, have been used as the basic grains in fattening rations has been determined largely by their cost or their availability in a particular locality. Certain individual characteristics of these cereals also play a part in determining their use for this purpose. For example, yellow corn, if used in large amounts, produces a high degree of colour in the skin and body fats which does not find favour in some markets. The high fibre content of oats and barley reduces the suitability of these grains as fattening feeds. Further, the effect of these grains on the gains made by the birds when fattened should be considered.

Jull (1) compared yellow corn meal, whole oats ground, and a mixture of ground corn, oats and buckwheat, supplemented by liquid buttermilk, as rations for fattening large roaster stock. The corn ration was found to be superior to the oat and the mixed cereal rations, and the mixed cereal ration was better than the oat ration on the basis of feed cost per pound gain in weight.

The object of this study was to determine the relative values of the whole cereals, when ground and supplemented by animal protein and salt, as rations for fattening roaster stock on a 21-day feeding period. A preliminary report of this work by Maw (2) gave the general effect of the rations upon the composition of the edible meat and fats in the carcasses.

STOCK AND METHODS

Mature-bodied Rhode Island Red cockerels were used. Nine groups of 3 birds each were allotted to each ration. The stock was confined to regular fattening crates for a period of 21 days. The individual initial weights were taken prior to the first feeding. The birds were weighed during the trial at the 7th and 14th day and again on the morning of the 22nd day in a starved condition.

The stock was group-fed, the feed for each group of 3 birds being recorded separately at each weekly period. The ration was full-fed 3 times daily in a wet state. The rations were made up as follows: the individual cereal, 93 lbs.; animal protein, 6 lbs. (containing 3 parts by weight of beef meal and 2 parts powdered buttermilk); and salt, 1 lb. The rations, when mixed for feeding, varied in their water content due to the differences in

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the water absorption of the cereals. The corn and barley rations took only slightly more than an equal weight of water to dry feed, whereas the wheat and oat rations needed approximately double the weight of feed in water for the desired wet consistency for feeding.

PERCENTAGE COMPOSITION OF THE RATIONS

Ration	Moisture	Ash	Fat	Fibre	Protein
Corn	9.02	4.06	4.04	1.5	14.78
Wheat	7.74	3.53	2.28	2.0	15.88
Oats	6.86	5.07	5.09	9.7	14.35
Barley	6.82	5.51	2.67	5.0	17.10

Table 1 presents the mean initial weight, gain in grams and in percentage for the 4 groups of birds. The group fed on corn had a larger percentage gain than any of the other groups. No difference was found between the groups fed wheat, oats, or barley. There was a considerable variability in the gains of the individual birds, and the variance analysis

TABLE 1.—MEAN VALUES OF INITIAL WEIGHT AND GAIN

Ration	Number of birds	Initial weight	Gain	Gain
		grms.	grms.	%
Corn	27	2747.59	387.04	14.09
Wheat	27	2846.66	292.59	10.28
Oats	27	2773.14	308.44	11.12
Barley	27	2728.51	285.55	10.46

showed that the ration groups did not differ significantly in the gains made after 21 days of fattening. However, some of this variability was brought about by the varying amounts of feed consumed. The gains were corrected by regression for this factor and Table 2 shows the analysis of the adjusted gains. It appears that the rations differ significantly in their effect on gain.

In order to determine the effect of the length of the feeding period on the adjusted gains of the four groups, the data were set up as shown in

TABLE 2.—ANALYSIS OF ADJUSTED GAINS (21 DAYS)

Source	D/F	S.S.	M.S.	$\frac{1}{2}\log_e$	S.D.
Between rations	3	66241.97	22080.65	6.0008	
Within rations	31	227321.40	7332.95	4.4501	85.632
Total	34	293563.37	z for rations = 1.5507		

Necessary z for significance 5% point .5353
1% point .7517

TABLE 3.—LENGTH OF FEEDING PERIOD AS INFLUENCING DIFFERENCES IN ADJUSTED GAINS (GRAMS)

Period—days		1 – 7		8 – 14		1 – 14		15 – 21		1 – 21	
Gains		Actual	Adjusted	Actual	Adjusted	Actual	Adjusted	Actual	Adjusted	Actual	Adjusted
Corn		100.77	59.94	169.33	76.32	270.11	235.37	116.66	161.72	387.04	359.06
Wheat		132.00	153.27	96.88	176.04	228.88	252.92	63.00	75.86	292.59	344.02
Oats		121.55	115.38	108.33	37.22	229.88	213.60	77.88	29.06	308.44	247.62
Barley		82.88	57.17	105.11	190.01	188.00	214.98	97.33	81.86	285.55	322.61
Necessary	P = .05	77.88		128.45		111.47		57.66		82.29	
Difference	P = .01	104.82		172.87		150.01		77.60		110.75	

Table 3. The necessary difference in grams for significance between any two groups is also shown. During the first 7 days the wheat-fed and the oat-fed groups made the best gains, the wheat-fed group having a significantly higher gain than the corn-fed and the barley-fed groups. From the 8th day to the 14th day the wheat-fed and the barley-fed groups were significantly better than the oat-fed group. At the 14th day there was no significant difference between the groups. From the 14th day to the 21st day the corn-fed group had higher gains than the other 3 groups. Finally, at the end of the trial, the corn-fed and the wheat-fed groups showed significantly better gains than the oat-fed group, with the barley-fed group in an intermediate position.

ANALYSIS OF THE DRESSED CARCASSES

Representative groups of three carcasses from each ration were selected for chemical analysis of the edible meat and fats. The skin and external fats adhering to the skin were separated from the muscle meat of the legs, breast, and wings and used as a separate sample; the muscle meat and perimuscular fats were taken as the second sample representing the flesh, and the abdominal fat, including that surrounding the gizzard and the proventriculus, was taken as the third sample. Each sample was ground until homogeneous, at which time small samples were taken for analysis of fat content by hydrochloric acid digestion (see method—Holcomb and Maw (3)).

In Table 4 is shown the fat content of the tissues. The greatest difference between rations in the amount of fat in the tissues is shown in the flesh sample; the corn-fed group showed the highest amount, 5.8% and the barley-fed, oat-fed and wheat-fed groups showed 4.2, 3.6, and 3.4% respectively. The skin samples vary less in fat content and show the wheat-fed group as having produced the largest amount, 34.0%, the oat-fed and barley-fed groups approximately the same amount, 33.0%, and the corn-fed group the least, 29.0%. The amount of fat in the abdominal fatty tissue varies in a different manner, the oat-fed group having 80.0%, the wheat-fed and the barley-fed groups the same, 77.0%, and the corn-fed group the least, 69.0%.

Table 4.—Fat content of the tissues

Cereal	Fat in flesh	Fat in skin	Fat in abdominal fat
	%	%	%
Corn	5.8	29	69
Barley	4.2	33	77
Oats	3.6	33	80
Wheat	3.4	34	77

In Table 5 is given the total fat content and the distribution of the fat in the edible portion represented by the three samples: flesh, skin, and abdominal fatty tissue. The percentage total fat varies slightly between the corn-fed and the wheat-fed groups, whereas the corn-fed group had approximately 10.0% more fat than the barley-fed and the oat-fed groups. The distribution of the total fat, as shown by the percentage of fat in the three parts analysed, suggests an effect of the cereal fed upon the deposition of fat in those parts. The corn-fed carcasses showed the largest amount

of fat in the flesh and the least amount of fat in the skin and abdominal fats. On the other hand, the wheat-fed carcasses carried the least amount of fat in the flesh and the most in the skin, and the second largest amount in the abdominal fats. The oat-fed and the barley-fed carcasses were intermediate in the amount of fat in the three parts.

TABLE 5.—DISTRIBUTION OF FAT IN THE EDIBLE PORTION

Cereal	Total fat	Flesh	Skin	Abdominal fat
	%			
Corn	13.4	30	55	15
Barley	12.1	26	59	15
Oats	12.1	22	57	21
Wheat	12.9	20	60	20

CONCLUSION

Data obtained from the fattening for 21 days of mature roasters with the ground cereals, corn, wheat, oats, and barley, supplemented by animal protein only, showed that the corn-fed and the wheat-fed birds made the best gains. The data suggest that corn and barley may be inferior to wheat and oats for short fattening periods. After 14 days, however, the cereals, corn, wheat and barley, were nearly alike in the amount of gain produced, with oats giving a somewhat lower value.

The corn-fed group produced the largest amount of total fat in the edible portion of the drawn carcass, whereas the barley-fed and the oat-fed groups showed the least fat and the wheat-fed group was intermediate.

The distribution of the total fat in the three parts, flesh, skin, and abdominal fatty tissue, suggests that the corn ration produces more fat in the flesh and less fat in the skin and abdominal regions. The wheat ration tends to show the opposite effect, producing more skin and abdominal fats and less flesh fats.

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THE CEREALS IN THE FATTENING RATION

II. THEIR COMPARATIVE VALUES FOR FATTENING LEGHORN BROILERS[1]

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The rations used for fattening poultry very often carry high percentages of ground oat groats or rolled hull-less oats. The oat is known to have a high feeding value for broilers. The economy of the hull-less oat product, however, is questioned when compared with the whole oat in ground form, as well as with the other common cereals used for similar feeding, such as ground whole yellow corn, wheat, or barley. Maw (1) has shown that, with large roaster stock fed for 21 days, either ground yellow corn or ground wheat, as a single cereal ration, is superior to ground whole oats. The ground hull-less oat or hull-less barley ration was not compared with the ground whole cereal ration. In order to determine the relative values of the 4 cereals, yellow corn, wheat, oats, and barley, as ground whole cereals, as well as the ground hull-less oats and hull-less barley, as rations for fattening broilers, a series of individual feeding trials was carried out.

STOCK AND METHODS

A group of 132 range-grown Leghorn cockerels, 10 weeks in age, was selected for uniformity in condition and weight, sorted into 6 lots of 22 individuals, and randomized on the basis of initial weight for cooping and feeding. Cooping conditions were similar to the regular fattening battery, although the cages were constructed for individuals rather than for groups of individuals. The stock was weighed-in for feeding on a starved basis. Individual feeding was carried on for a period of 14 days, weight, gain, and feed consumption being recorded at the 7th and 14th days.

The rations used were made up of 93 pounds of the ground individual cereal to which was added 6 pounds of animal protein feed, made up of 3 parts beef meal and 2 parts powdered buttermilk by weight, and 1 pound of salt.

Table 1.—Chemical composition of the rations

Ration	Moisture	Ash	Fat	Fibre	Protein N. × 6.25
Corn	9.02	4.06	4.04	1.5	14.78
Wheat	7.74	3.53	2.28	2.0	15.88
Oats	6.86	5.07	5.09	9.7	14.35
Barley	6.82	5.51	2.67	5.0	17.10
Hull-less oats	8.65	3.69	7.22	1.9	23.19
Hull-less barley	9.72	3.47	3.27	2.0	17.21

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As would be expected, the 6 rations vary somewhat in their chemical composition. The fat content varies most widely, showing wheat as being the lowest with 2.28% and hull-less oats the highest with 7.22%. The whole ground oats carried 5.09%, being closely similar to wheat. The hull-less barley carried only 3.27% fat. In protein content, however, the 4 ground whole cereal rations were fairly close, although the barley ration was highest with 17.10% as compared to the oat ration which was lowest with 14.35%. The hull-less oats and barley rations showed some increase, although the barley ration was only slightly higher in protein content than the ground whole barley ration, while the hull-less oat ration showed a high protein content of 23.19% in comparison to the ground whole oat ration with 14.35%.

The individual birds were fed 3 times daily at 7.00 a.m., noon, and 5.30 p.m., allowing approximately 30 minutes for feeding. The dry feed was mixed with water to a consistency carrying approximately 65% moisture, but no free-water was showing on the mixed feed in the troughs.

RESULTS

In Table 2 are shown the general data resulting from the individual feeding of 22 birds on each ration, giving the initial weights with the percentage gains and the gain-feed ratios for the 7-day and 14-day periods. It is to be noted that the length of feeding period has a significant effect upon the percentage gain with all rations fed. With the exception of the

TABLE 2.—INITIAL WEIGHTS WITH COMPARATIVE GAINS AND GAIN-FEED RATIOS FOR SEVEN-DAY AND FOURTEEN-DAY FEEDING PERIODS

	Ration	Number of birds	Initial weight	Fattened 7 days		Fattened 14 days		Gain-feed ratio	
				Gain	Gain	Gain	Gain	7 days	14 days
			(gms.)	(gms.)	(%)	(gms.)	(%)		
I	Corn	22	795.68	97.73	12.28	221.36	27.82	16.62	20.41
II	Wheat	22	820.23	103.41	12.60	241.82	29.48	17.21	21.35
III	Oats	22	753.18	156.14	20.73	320.45	42.54	23.53	23.50
IV	Barley	22	802.04	107.50	13.40	248.41	30.97	18.68	21.85
V	Hull-less Oats	22	749.77	133.64	17.82	252.04	33.61	24.17	23.30
VI	Hull-less Barley	22	775.23	121.82	15.71	253.86	32.74	22.46	23.64

hull-less oat ration, all 14-day gains are more than double those made in the 7-day period. On the basis of the gain-feed ratio, however, both oat rations were as efficient on the 7-day period as on the 14-day period. Hull-less barley was also approximately as efficient on the 7-day period as the 14-day period, whereas the other 3 rations were decidedly more efficient on the 14-day period than on the 7-day period.

INFLUENCE OF RATIONS ON GAIN

In Table 3 will be noted the actual live-weight gains made on the 7-day and 14-day periods, as well as those gains when adjusted on the basis of the feed consumed for comparison on an equal feed-intake basis. On the 7-day basis it is to be noted that, where the necessary difference for sig-

nificance between any two rations is 29.56 on the 5% basis, the oat, hull-less oat and hull-less barley rations are better than corn or wheat, while the hull-less oat ration only is significantly better than the barley ration. Corn, wheat, and barley are of equal value. Where the feeding period is extended to 14 days the necessary difference for significance on the 5% basis is 33.64. It will be noted that the hull-less barley ration is the only ration significantly better than any other one, being superior to corn. Corn, however, is equal to any one of the other 4 rations.

Table 3.—Gains adjusted for feed consumed

Ration	Fattened (7 days)		Fattened (14 days)	
	Actual gain	Adjusted gain	Actual gain	Adjusted gain
	(gms.)	(gms.)	(gms.)	(gms.)
Corn	97.73	97.45	221.36	240.06
Wheat	103.41	99.08	241.82	245.82
Oats	156.14	131.87	320.45	253.65
Barley	107.50	111.19	248.41	250.91
Hull-less oats	133.64	144.54	252.04	271.34
Hull-less barley	121.82	136.10	253.86	275.96
Necessary difference 19 : 1	29.56		33.64	
99 : 1	39.26		44.68	

Tables 4 and 5 present the analysis of the variance of gains for the 7-day and 14-day feeding periods. The data for the 7-day period show a z value of 0.6449 for diets for the adjusted gains. In the case of the 14-day period the z value for diets of 0.7892 for the actual gains is reduced to 0.1747 when the gains are adjusted for feed consumption. The necessary z value for significance at the 5% level is 0.3974. The effect of diet is apparently due to the quantity of feed consumed rather than any differences in the quality of the rations. It would appear that certain of the rations give better gains than others in the early part of the fattening period, and that these differences are reduced by a longer feeding period.

Table 4.—Analysis of gains (7 days)

Source	D/F	S.S.	M.S.	$\frac{1}{2}\log_e$	S.D.
Between blocks	21	120412.32	5733.92		
Between rations	5	53298.68	10659.73	4.6367	
Error	105	369213.82	3516.32	4.0825	59.30
Total	131	542924.82	z for rations = 0.5542		
Analysis of adjusted gains					
Between blocks	21	83634.63	3982.60		
Between rations	5	44580.10	8916.02	4.5478	
Error	104	255387.21	2455.64	3.9029	49.55
Total	130	383601.94	z for rations = 0.6449		

TABLE 5.—ANALYSIS OF GAINS (14 DAYS)

Source	D/F	S.S.	M.S.	$\frac{1}{2}\log_e$	S.D.
Between blocks	21	140372.20	6684.39		
Between rations	5	123912.30	24782.46	5.0589	
Error	105	587858.00	5111.81	4.2697	71.49
Total	131	852142.50	z for rations = 0.7892		
ANALYSIS OF ADJUSTED GAINS					
Between blocks	21	70268.65	3346.12		
Between rations	5	22522.76	4504.55	4.2065	
Error	104	330390.99	3176.83	4.0318	56.36
Total	130	423182.40	z for rations = 0.1747		

ANALYSIS OF THE FINISHED CARCASSES

After being dressed and chilled, 5 carcasses were selected from each of the 4 groups, corn-fed, wheat-fed, oat-fed, and barley-fed, for chemical analysis. The carcasses were drawn and boned, and the edible portion of each drawn carcass was separated into 4 samples, white meat, dark meat, skin, and abdominal fat, as described by Maw *et al.* (2).

The method of chemical analysis used was that described by Holcomb and Maw (3).

In Table 6 are shown the results of the physical separation of the edible meat and fat. Relatively no differences were shown in the relationship of the total edible portion to the dressed weight according to the ration fed. The corn-fed stock had a larger amount of abdominal fat than any other group. The weight of the skin was also greater than that of the other groups. The skin weight is influenced by the amount of external fat on the carcass. It is, therefore, apparent that the corn-fed group carried more fat on the carcass (see Table 7). In all groups, except the corn group, the weights of the white and dark meats were approximately even; the corn group, however, showed a definitely larger weight of dark meat. Here again, the amount of dark meat is influenced by the fat content of that part.

TABLE 6.—ANALYSIS OF THE DRESSED CARCASSES: WEIGHTS OF THE EDIBLE MEAT, FAT AND SKIN (ALL WEIGHTS IN GRAMS)

Cereal	Dressed weight	Abdominal fat	Skin	White meat	Dark meat	Total edible	Percentage of dressed weight
Corn	870	10	71	148	163	392	45.05
Wheat	813	6	57	164	158	385	47.35
Oats	897	8	67	167	166	408	45.48
Barley	929	7	67	180	174	428	46.07

DISTRIBUTION OF FAT

In Table 7 is shown the fat content of the edible parts, as shown by chemical analysis, as well as the relationship of the fat content of any part to the total fat content of the edible portion. Assuming that the different groups before treatment were relatively uniform in the percentage of body fat, the 4 cereals appear to vary in their effect upon fat production in the carcass. Corn produced the highest amount, 11.29%; oats, second, with 9.09%; barley, third, with 8.32%; and wheat was last with 7.97%. On examination of the data for the various parts, it is noted that the corn-fed stock carried more fat in each part, showing a heavily fatted condition throughout the body. In contrast with the other cereals, the corn-fed group did not carry as much fat in the meat area in relation to the total fat in the body. Relatively little difference was shown in the proportion of fat in the skin as between any pair of rations. The greatest differences were noted in the proportion of the total fats in the abdominal fatty tissue, corn having the highest percentage, with barley and oats about equal, and wheat the lowest. In the meat area the proportions were reversed, with wheat carrying the highest amount, corn the lowest amount, and oats and barley being intermediate. Such results suggest some possible effect of the ration fed upon the distribution of fat in the body.

The data were analysed by variance on the basis of the proportion of the total fat as found in any one of the 4 parts under study: abdominal fat, skin, light meat, and dark meat. The results showed no effect from the diet fed. In all edible parts the variation (within birds) in the amount of fat on a given ration was great.

TABLE 7.—ANALYSIS OF THE DRESSED CARCASSES: PERCENTAGE FAT IN THE EDIBLE MEAT AND FAT

—	Average dressed weight	Abdominal fat	Total fat	Skin	Total fat	White meat	Total fat	Dark meat	Total fat	Total meat	Total fat	Total edible
	(gms.)		(%)		(%)		(%)		(%)		(%)	
Corn	870	84.7	17.9	29.6	48.3	4.1	14.0	5.2	19.7	4.7	33.9	11.29
Wheat	813	72.3	11.9	24.4	46.2	3.1	17.9	4.5	23.9	3.8	41.8	7.97
Oats	897	69.5	15.7	24.9	47.6	3.6	17.8	4.6	22.0	4.1	39.8	9.09
Barley	929	78.8	16.0	23.4	46.8	3.1	16.4	4.6	22.3	3.8	38.7	8.32

CONCLUSIONS

Any one of the 6 cereals, yellow corn, wheat, whole oats, hull-less oats, whole barley, or hull-less barley in ground form, where supplemented with 6% protein (beef and milk) and 1% salt, is equally good in fattening Leghorn broilers for a 14-day period.

Where fed for 7 days only, either the whole oat, the hull-less oat, or the hull-less barley ration was superior to the corn or wheat ration, and the hull-less oat ration only was significantly better than barley on the basis of gain.

On the basis of the gain-feed ratio both oat rations were equally efficient on either the 7-day or the 14-day period. Hull-less barley was

approximately as efficient on the 7-day as the 14-day period. Corn, wheat, and barley rations were most efficient on the 14-day period.

The length of the feeding period appeared to have an effect on the gains made where broiler stock was fed on rations made up of the single cereals studied.

Corn produced the largest amount of fat in the carcass and gave the best distribution of fat throughout the edible meat and fat portions. Oat, barley, and wheat rations, respectively, produced less fat.

The rations fed had no significant effect upon the distribution of fat in the edible portion.

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BOOK REVIEW

GILBEART H. COLLINGS—"Commercial Fertilizers, Their Sources and Use." P. Blakiston's Son & Co., Inc., Publishers, No. 1012 Walnut Street, Philadelphia, Pa. $4.00.

In this publication the author has presented information on the manufacture and use of fertilizer materials in greater detail than is usually found in books dealing with this subject. The growth and development of the use of commercial fertilizers has been traced through the 19th and 20th centuries and attention drawn to the losses of plant food constituents from the soil.

An interesting feature of this treatise is the description of the development of the more important nitrate, phosphate and potash deposits of the world. The principal processes of manufacture of nitrogenous fertilizers, superphosphates and potash salts have been dealt with in considerable detail and have been illustrated with numerous photographs. The relative merits of the various sources of nitrogen, phosphoric acid and potash have been discussed in the light of results obtained by a large number of research institutions; and practically all by-products which have any appreciable fertilizing value have been included.

One chapter is devoted to the discussion of the uses of fertilizers carrying elements other than nitrogen, phosphoric acid and potash, which are essential to plant growth, for example, sulphur, calcium, magnesium, iron, manganese, boron, copper and zinc. Reference is made to the results obtained in many researches conducted by agricultural institutions and the theories of the investigators on the part played by these elements in plant metabolism are given.

This book concludes with a discussion of the principles underlying the use of fertilizers, methods of application and the influence of soil reaction on the availability of the several plant food elements. In this section the author does not attempt to outline definite recommendations for special crops but draws attention to the main factors which influence the kinds and amounts of the plant food elements to be employed.

In conclusion it may be stated that the book under review should prove of particular value as a text book for students at agricultural colleges since it gives up-to-date information on the production of fertilizer materials and also presents the recent views of scientific agricultural investigators on the principles underlying the use of fertilizers generally. A very complete bibliography is included enhancing its value for reference purposes.

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